NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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UNDERGROUND STORAGE AND GROUND WATER RECHARGE IN THE ELAZIG-ULUOVA PLAIN, TURKEY.

by Dr. Geol. Ali Ozkan, Director, Investigation and Planning Section, Ground-Water Division, Directorate General of State Hydraulic Works, Ankara, Turkey.

A - INTRODUCTION

Uluova Plain which spreads over a superficial area of 30,000 hectars is one of the most important agricultural centers of the south-eastern part of Turkey. Its soil property is suitable for growing most crops, and the whole area is actually under cultivation. Its population which counts 140.000, is mostly engaged in farming as the principal occupation.

The temperature is high. The precipitation is very low, and nonuniformly distributed throughout the year. Usually, the plain has an extended rainless period, during the growing season. For these reasons precipitation is insufficient, therefore irrigation becomes a must for the agricultural economy of this area.

Surface water supply being insufficient, a great portion of the plain must be irrigated with water from Under-ground sources. Actually dry-farming is practised in the major part of the area.

Several studies have been made concerning the geology of the plain and the adjoining areas during the last 15 years, and a hydro-geological inventory has been made by DSI in 1956. 23 test wells were drilled in 1957 by the Ground Water Division of DSI. A preliminary groundwater planning report has been completed in 1958, and 46 Production wells were drilled in 1959. Actually very little information is available concerning the hydrological features of the area, outside of those mentioned above. The reports on these studies, and the records of existing wells proved helpful in the preperation of this paper.

B - GEOGRAPHY

(a) Location and extent of the area:

Uluova Plain is located in South-Eastern part of Turkey, between latitudes 38° 30' and 38° 50', and longitudes 42°00' and 42°40'. It is bounded on the north, south and on the west by mountains, and on the east by Murat-River. The plain extends from west to east, measuring about 30 Km. from south-west to north-east, and about 10 Km. from north to south with an area of 30.000 hectares. The city of Elâzig, which is located in the western part of the plain, is the capital city of the province of the same name , has a population of 65,000.

(b) Topography and Drainage:

Uluova Plain lies within the Firat Basin Region, and is drained by the tributaries of the Murat River, which itself is one of the largest tributaries of the Firat River. Harinket Stream flows in a SW-NE direction across the plain and spills into the Murat River.

The plain is surrounded in the North, South and West by Hills and mountains with an average elevation of about 1600 m. The highest altitude in this area, is in the south of the plain and measures 1650 m, and the lowest point is in the NE of the plain and measures 825 m., the total relief, therefore, being about 825 meters. Generally the plain has a flat topography, and gently slopes down from south-west to north-east.

The elevations are 950 m. and 825 m. in the south-western and north-eastern parts, respectively the general slope being about 2.9% from SW to NE.

Harinket is a perennial stream, although its flow shows seasonal variations. Its tributaries do not have continuous flow, and surface runoffs only occur following precipitations.

(c) Climate:

The Uluova Plain is situated in the south eastern part of Turkey where semi-arid climate prevails, which is characterized by a low precipitation, a high rate of evaporation and a wide range in temperature.

According to records the average annual precipitation for the 20 year period 1930-1950 is 440.4 mm., the largest part of the annual precipitation occuring in the form of snow during the winter, and leaving only a very small part for the crop growing season. Only 4.4% (19.5 mm.) of the total annual precipitation occurs during the months of June, July and August.

The mean annual temperature is 12.9°C. The difference between the maximum summer and the minimum winter temperatures is quite large. The lowest temperature during the year is in February (-19.4°C.), and the highest is in July (42°C).

Wind velocities are highest during the spring and keep diminishing until they reach a minimum in December.

The average climatic data, recorded at Elâzig station is given in table 1, and the annual precipitation, evaporation, and temperature are shown in Figures 1-111

TABLE 1.
AVERAGE CLIMATIC DATA RECORDED AT ELAZIG STATION IN ULUOVA PLAIN

Station	Annual Precipitation (mm.)	TEMPERATURE (DEGREES C)				Duration of growing season (days)
		Max.	Min.	Average July	Average February	
Elâzig	440.4	42.0	-19.4	27.2	-0.5	210

(d) Population, Agriculture and Industry:

According to the 1960 Census, the population of the area is 140.000. There are 47 villages and only one town in the area. Approximately 60 percent of the population live in small villages. The only town in the plain is Elâzig, with a population of about 65,000.

Farming is the principal occupation in the area. 32,000 hectares of land are actually under cultivation and about 97% of it is irrigable. The character of soil is generally good, and only 4,000 hectares of land are actually irrigated by surface waters.

Grains, cotton, sugarbeet, vineyards, vegetables and horticulture are the principal crop patterns.

The major industry in the area is agricultural product processing. One sugar refinery, one cement factory and several flour mills are located in and near Elâzig. There is a variety of small manufacturing concerns operating in this town.

The area is served by railways. The main railway line between Instanbul and Diyarbakir crosses the area from west to east.

Communication with neighbouring villages and other towns is established by means of state highways and several graded secondary roads.

C - HYDROLOGY:

(a) Streams:

Harinket Stream and its tributaries drain the area from its surface waters. This stream flows across Uluova Plain in a south west-north east direction.

The total drainage area of Harinket stream is 934 sq km. The annual rate of flow of this stream is estimated to be about 110 x 10^6 cu.m. Harinket stream is a perennial stream, but its rate of flow is not uniform throughout the year, being high during the winter season and spring; and low in the Summer. The highest rate of flow occurs in spring, and the lowest in the late summer.

Harinket stream irrigates 4,000 hectares of land.

(b) Lakes:

The only lake in this area, namely the Hazer is located in the mountainous region in the southern part of the plain. Its surface elevation is 155 m. higher than the average elevation of the Uluova Plain. High mountains, that are located in the periphery make the Hazer Lake a closed basin. The surface area of the lake is 84 sq.km., and its maximum depth is 300 m.

Water from Hazer Lake is conducted down hill by means of a diversion tunnel to a power plant where electrical power is generated.

(c) Springs:

There exist numerous springs in the area surrounding Uluova plain. These springs issue from the joints, fractures and openings of igneous rocks and marbles. There are also a number of small springs and seeps in eocene flysch formations, which usually issue at the contact of sandstones or conglomerates and the underlying shales.

Most springs in the area have small yields. But some of them discharge as much as 30 litres per second. Generally, the largest springs of the area issue from limestone and marbles.

These springs are generally used to meet domestic water demands.

(d) Dug Wells

There are about two hundred dug wells in the plain. These wells are usually excavated with hand tools, the diameter generally varying from 1-2 meters and the depth between 5 and 15 meters.

These wells are recharged from a shallow aquifer, which is located in the upper portion of the alluvium. The static water level lies generally within 1 or 2 meters from the surface in the central part of the plain, and between 5 or 8 meters in the other parts of the area. The water-level fluctuations occur with seasons; the rise varying between 0.5 and 1 meter during winter and fall, and between 4 and 8 meters in late summer.

Dug wells are usually located in the villages and are used for domestic and animal stock water supplies. These wells are not sealed and can be easily contaminated in many ways.

(e) Deep Wells:

23 exploratory, 46 production and 5 drinking water wells have been drilled in unconsolidated deposits of the plain by DSI in 1957 and 1958. Rotary rigs were used in drilling and the wells were cased with galvanized-iron casings, ranging from 4-12 inches in diameter. For pump setting reasons, 8 inches or larger diameter casings were used in the first 40 meters from the top.

17 of these wells, which were drilled in the central part of the plain, are flowing and the rest are non-flowing. The depth of test wells ranges between 100 and 300 meters, that of the production wells is 120 m.

The yields of flowing wells are variable. Some of them yield between 80 and 100 litres of water per second, and the rest have yields averaging between 10 and 30 litres per second. The artesian head in these wells vary between + 1 and + 10 meters.

The average discharge of existing non-flowing wells is 30 litres per second, and the pumping lift varies between 5 and 20 meters.

Almost all of the flowing wells are actually used by farmers for irrigation and 8 of the non-flowing wells are operating for drinking water supply purposes. 8 pump operated wells will be used by DSI for irrigation demonstration in 1963.

D - GELOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES:

The formations that crop out in Uluova Plain and the adjacent areas, are sedimentary, metamorphic, and igneous rocks, and range in age from late paleozoic to recent. The areas where these formations lie are shown on Fig. 1X.
As seen on the geologic map, Uluova Plain is underlain by alluviums and terrace deposits. The other formations, mentioned above, crop out in the mountainous areas that surround the plain. These formations are of relatively low permeability and usually yield small quantities of water to springs.

The unconsolidated materials of Recent and Pleistocene age of Uluova Plain are the principal sources of groundwater in this area. Ground Water in sufficient quantities for irrigation and other supplies is contained in these deposits. The thickness of these materials in the plain ranges from 50 to 300 meters. These deposits contain thick lenses of sand and gravel and yield large quantities of water to wells.

A generalized section of the geologic formations that are exposed in the area, is given on table 2.

E - GROUND-WATER

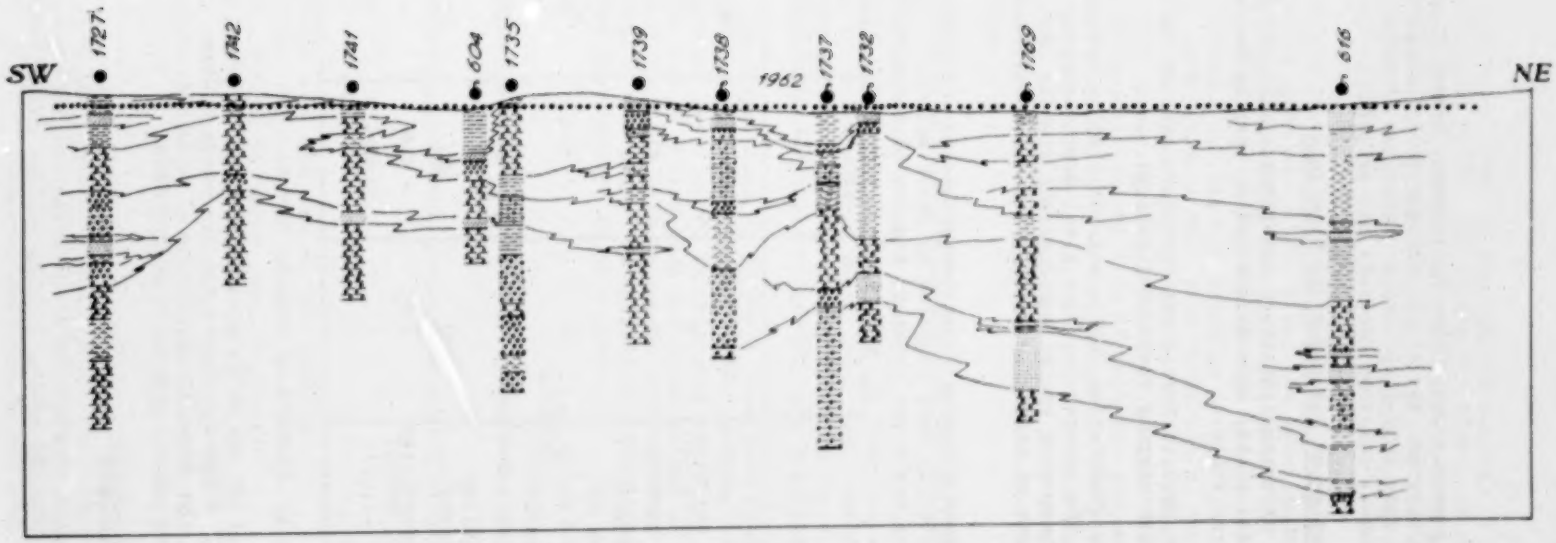
(a) Occurrence:

The principal sources of groundwater in Uluova Plain are the younger and older alluviums, and the terrace deposits. The maximum thickness of these materials is estimated at 300-350 meters. 250 m. deep test wells, drilled in alluvium and terrace deposits, have not reached the bedrock yet that underlies these formations.

There is a shallow water-table aquifer in the upper portion of the unconsolidated deposits in the plain. The water quality of this aquifer is suitable for irrigation, but its permeability is low. Evaporation and transpiration have a marked effect on this aquifer, which therefore yields very small quantities of water.

Below 60., water in these deposits is under artesian pressure. These water bearing materials are coarse sand and gravel, interbedded with clay, silt or sandy clay.

Artesian aquifers are generally interconnected and show only very slight differences between different zones, as to quality of water the piezometric level and other characteristics.



GEOLOGIC SECTION OF ULUOVA PLAIN

Scale

0 1 2 kilometers

Vertical scale 10 times horizontal scale.

EXPLANATION

- Gravel
- Gravel and sand
- Sand
- Sandy clay
- Clay and gravel
- Clay
- Silt
- 1962 — Profile of piezometric surface
- 1742 — Non-flowing well
- 1738 — Flowing well

Marbles, basic igneous rocks, Upper Cretaceous, Eocene flysch formations, and basalt lavas that surround the plain, are generally unimportant as groundwater sources; they only yield small quantities of water to a few springs through fractures, solution channels and joints.

(b) Hydrologic Properties of Water-Bearing Materials:

The co-efficient of transmissibility and permeability of unconsolidated deposits covering Uluova plain, were determined by pumping tests, that were performed on exploratory wells.

The step-drawdown test in four steps were made on each well for a period of 72 hours, with varying rates of discharge.

Unfortunately, no observation wells were drilled in artesian aquifer for measuring the changes in water level during pumping tests; water level had to be measured in the pumping well itself. For this reason, the co-efficient of storage, and radii of influence could not be determined.

From the data gathered during these tests, the co-efficients of transmissibility and permeability were computed by jacob method. The results of the tests on several wells are shown in figures IV-V and Table 3.

	WELL NOS		
	1741	1742	2591
Date of test.....	Oct. 1961	Nov. 1961	Nov. 1961
Duration of test (Hours).....	6	3	2.5
Pump discharge (litres per second).	14	20	2
Specific capacity of pumped well (litres per second per meter of drawdown).....	2	8.5	0.2
Saturated Thickness of formation (meters).....	50	46	2.10
Co-efficient of transmissibility (Cubic meters per day per meter)...	125	207	47
Average co-efficient of permeability (Cubic meter per day per SQ. meter)	2.5	4.6	-
Co-efficient of storage.....	-	-	22×10^{-3}

Table 3. Results of pumping tests.

Specific capacities of the wells generally range between 2 and 10 litres per second per meter of drawdown. Where the thickness of sand and gravel beds in alluvium was large, the specific capacities of the wells were usually higher than 5 litres per second per meter of drawdown.

(c) Water-level Fluctuations:

Periodic measurements of water-level fluctuations in Uluova plain were begun in the fall of 1960. 48 wells, tapping shallow unconfined and deep artesian aquifers, are used for observation purposes.

The water level in the shallow aquifer is associated with evapo-Transpiration, and fluctuates widely in response to precipitation, temperature, and evaporation. In shallow observation wells, the highest water level was measured in early spring, and the lowest in the late summer. The difference between maximum and minimum water levels is as high as 10 meters.

Since only a few wells tapping the deep aquifer are being used for irrigation purposes in the plain, no relationship could be established between the fluctuation of the piezometric surface and the discharge from wells. The main factors causing declines in the piezometric surface of the deep artesian aquifer are recharge by precipitation and discharge by seeps. Ground water studies that were conducted in the plain have shown that, groundwater is recharging from Harinket stream in the south-west and discharging into this stream, in the north-east. Therefore, it can be concluded that, precipitation and flow of Harinket stream have an effect on the piezometric surface of artesian aquifer in Uluova Plain, which effect is manifested in the seasonal variations, observed in the piezometric surface of ground water (fig VI). The annual rate of fluctuations in the observation wells, tapping and artesian aquifer, ranges between 0.5 and 3 meters.

(d) Ground Water Storage Capacity and Recharge.

Ground water storage capacity, as used in this paper, means the volume of water that would drain by gravity from the water-bearing materials underlying the plain, if the water level were lowered to the bottom of the water bearing zones. In other words, it means the volume of water required to resaturate the deposits after they are complately drained.

The logorithims of 69 wells have been used for estimating the total groundwater storage capacity of Uluova Plain. The volume of each type of material was figured individually according to the corresponding logorithims and by multiplying the total volume of deposits by the corresponding value of specific yield given on table 4, the total groundwater storage capacity of the plain was estimated. The figure found slightly exceeded one billion cubic meters in this case.

Table 4

Specific yield used to estimate groundwater storage capacity in Uluova Plain.

MATERIAL	ASSIGNED SPECIFIC YIELD (PERCENT)
Gravel; sand and gravel, and related gravelly deposits	25
Sand, medium to coarse grained, loose and wellsorted.....	25
Fine sand; tight sand; tight gravel; and related deposits.....	10
Gravelly clay; sandy clay, and silt.....	5

This however is not the usable ground water storage capacity. The usability of the ground water storage capacity, of course, is dependent on cyclic recharge, transmissibility and permeability of water-yielding materials, also on some economic factors.

According to the studies conducted in the plain, the maximum economic pumping lift for a ground-water irrigation operation is 20 m. in this area. By considering this factor, usable ground water storage capacity in Uluova Plain was estimated to be 90 x 10^6 cubic meters. But, in order to make use of this much storage capacity, the same volume of water must be recharged every year through precipitation or other means, so that the ground-water level will not recede beyond 20 m. from the ground surface.

In Uluova Plain ground-water is recharged primarily by precipitation. Other sources for recharge are surface streams and irrigation water. By way of hydrologic inventory the annual recharge of groundwater in Uluova Plain is estimated to be 38 million cubic meters from precipitation, 30 million cubic meters from streams, and 4 million cubic meters from irrigation water.

The general direction of groundwater flow is toward the River Murat from SW to NE. Groundwater is discharged into the Harinket stream and the River Murat in the North Eastern part of the plain. The annual rate of discharge is estimated to be 22 x 10^6 cubic meters. Therefore, the quantity of water which is stored annualy in the water bearing materials of Uluova Plain, is about 50 x 10^6 cubic meters, and this should be the annual safe yield of ground water for this plain.

(e) Chemical Quality of the Ground Water:

The quality of water in the springs, the streams and wells located in the plain and its vicinity, is generally suitable for drinking and irrigation purposes. As it can be seen in Fig V111, both surface and ground waters in the plain belong to the C_2S_1 class. Lake Hazer, which is merely a closed basin located in the mountainous area south of Uluova, contains a high concentration of salt water, which naturally is not suitable for irrigation.

Total quantity of dissolved solids contained in spring and stream waters varies between 7.40 and 19.96 EPM, and the electrical conductivity of these waters varies between 340 and 410 micromhos at 25°C.

The total quantity of dissolved minerals in the ground water varies between 6.70 and 12.02 EPM and the electrical conductivity of the ground-water varies between 280 and 600 micromhos at 25°C.

The quantity of dissolved minerals, the hardness, the electrical conductivity and the quantity of the various chemical elements, found in the spring waters issuing from volcanic formations in the periphery of the plain, are lower than those found in the other types of formations.

Calcium cations and HCO_3 anions are the main ions in the artesian water in the plain. The water is nearly saturated with $CaCO_3$. Dissolved mineral contents increase gradually in the direction of ground water flow.

The semi-logorithmic diagram in Fig V11 shows the relation between the water samples taken from a well drilled in the plain, from the Harinket stream and from Lake Hazer separately. As can be seen from the diagram, there is a close resemblance between the quality of the ground water and that of the Harinket stream water, while the water from Lake Hazer is totally different. The electrical conductivity value of the lake water is 3400 micromhos at 25°C and its irrigation water classification is C_4S_3. High salinity is due to Na C_1 and Na HCO_3.

F - POSSIBILITY OF APPLICATION OF AN IRRIGATION PROJECT IN THE PLAIN:

There are about 30,000 hectares of irrigable land in Uluova Plain. Actually only 400 hectares of land are being irrigated by surface water. Early results of ground water studies have shown that 8000 hectares of land can be irrigated by ground water. It is then evident that the remaining 18,000 hectares of land must be irrigated by pumping from River Murat, which is the only way, but uneconomical.

In a prospective ground-water irrigation project in the plain, the wells to be drilled should have an average depth of 120 m., a maximum pumping lift of 20., and an average yield of 30 litres per second. Since 1 litre of water per second is required to irrigate 1 hectare of land, each well would irrigate an average of 30 hectares of land, and 260 wells would be necessary.

Results of studies have shown that the most economicl crop pattern to be adopted in a ground-water irrigation project in the plain consists of cotton, sugar-beet, and vegetables. Use of electric power is more economical than any other type of power for a ground-water irrigation operation in this plain, and the return-to-cost ratio is 6.4.

G - CONCLUSION:

The principal sources of ground-water in Uluova Plain are the unconsolidated deposits. There is a shallow unconfined aquifer in the upper 25 m. zone. The storage capacity of this aquifer is limited, and it can only supply very small quantities of water to some domestic wells.

The main productive aquifer in the plain is a confined or semi-confined layer which usually lies between 60 and 125 meters from the surface.

The quality of the ground-water is generally suitable for irrigation and drinking purposes.

Ground-water is recharged principally by precipitation. The total annual recharge of ground-water from precipitation, surface streams and irrigation water combined is estimated to be 72 x 10^6 cubic meters. 22 x 10^6 of this being discharged by seeps, the estimated annual safe yield of ground-water in the plain is about 50 x 10^6 cubic meters. These figures are based on short-term hydrological observations. For reasons of accuracy in estimating the usable storage capacity of the plain, additional studies, experiments and observation work are being conducted on wells and surface waters.

According to results obtained so far, ground-water irrigation is feasible and should be practised in this plain.

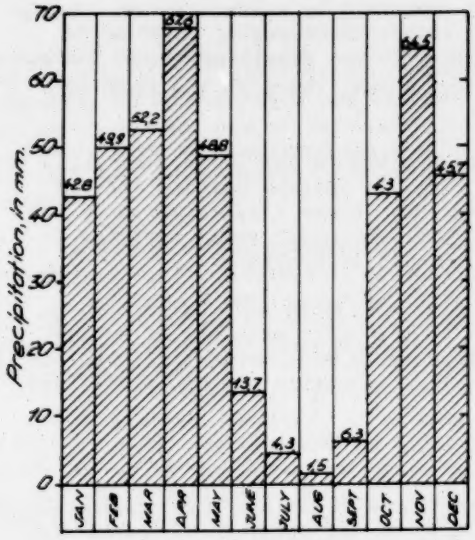


Fig. I - Graph showing the normal monthly precipitation at Elazig

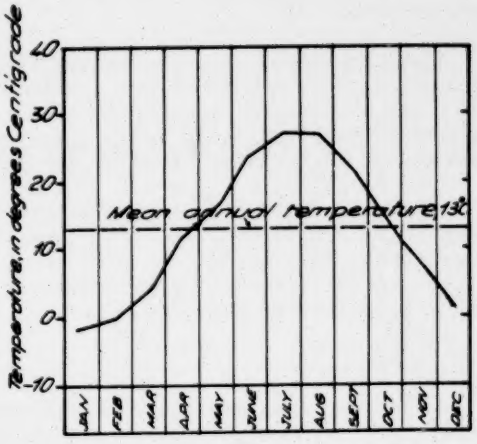


Fig. II - Mean monthly temperature at Elazig

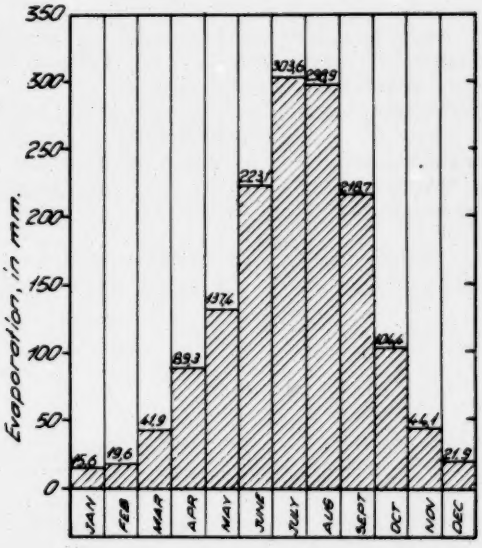


Fig. III - Graph showing the normal monthly evaporation from free water surface at Elazig

Note:

These graphs are based on data, collected from official climatological bulletins, for the period 1930 - 1950.

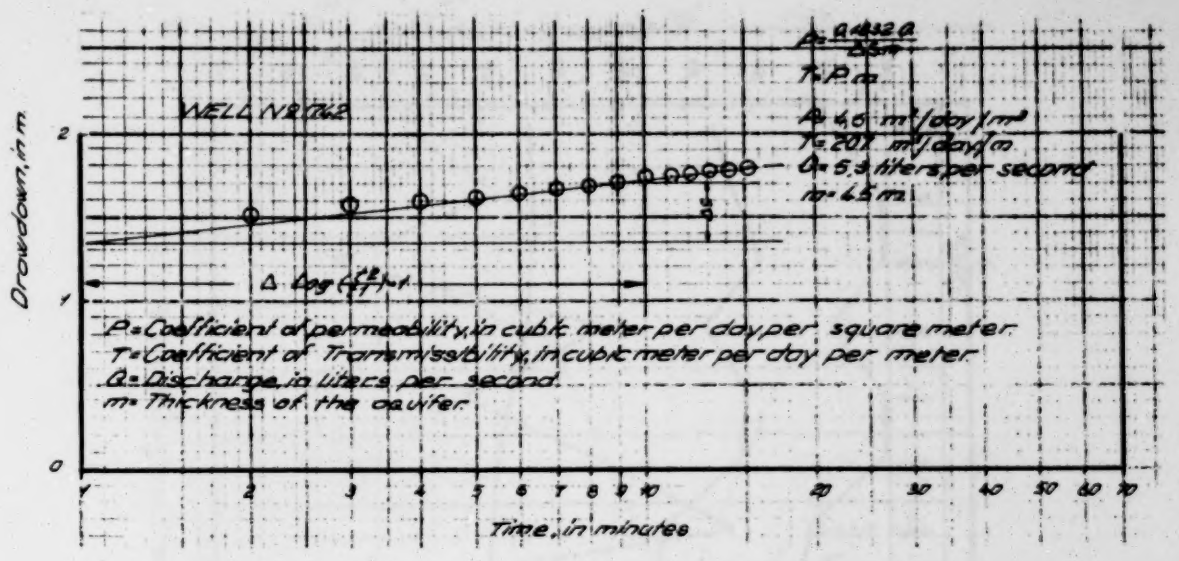

WELL Nº 1762
T = 0,1832 Q / Δs
T.P.m.
P = 4,6 m³/day/m²
T = 207 m³/day/m
Q = 5,3 liters per second
r = 6,5 m.
Δ Log (t2/t1) = 1
P = Coefficient of permeability, in cubic meter per day per square meter.
T = Coefficient of Transmissibility, in cubic meter per day per meter.
Q = Discharge, in liters per second.
m = Thickness of the aquifer.
Drawdown, in m.
Time, in minutes

Fig. IV - Coefficient of Transmissibility determined by Jacob method

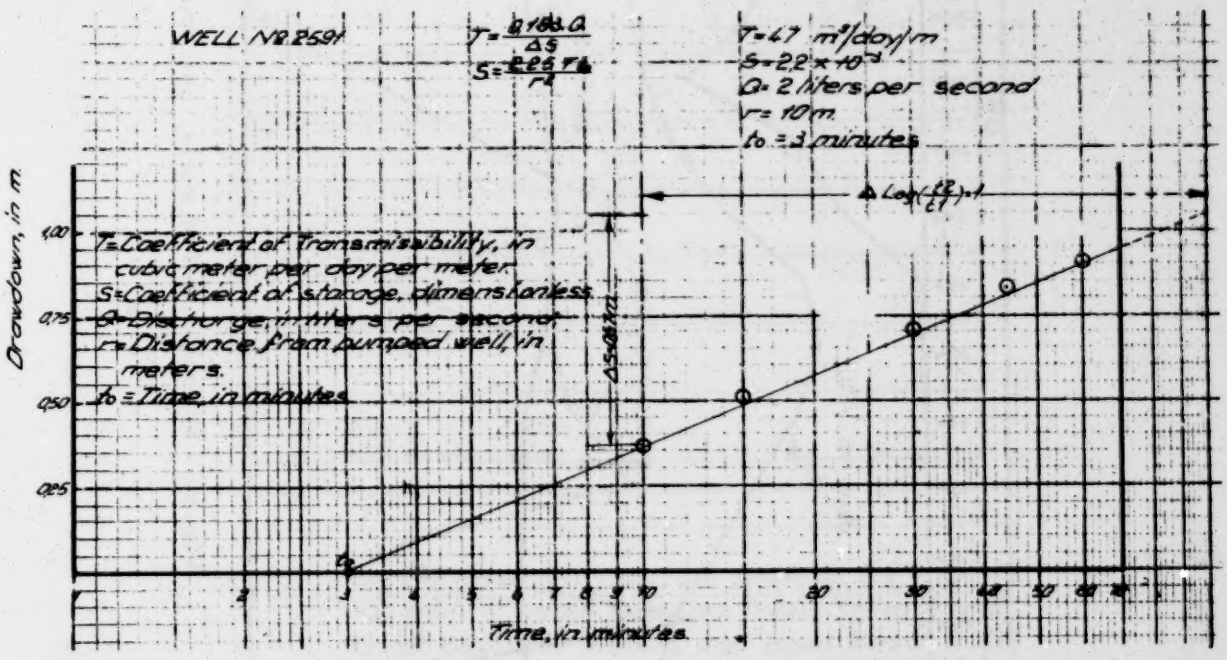

WELL Nº 2591
T = 0,183 Q / Δs
S = 2,25 T t0 / r²
T = 47 m³/day/m
S = 2,2 x 10⁻³
Q = 2 liters per second
r = 10 m.
t0 = 3 minutes
Δ Log (t2/t1) = 1
Δs = 0,25 m.
T = Coefficient of Transmissibility, in cubic meter per day per meter.
S = Coefficient of storage, dimensionless.
Q = Discharge, in liters per second.
r = Distance from pumped well, in meters.
to = Time, in minutes.
Drawdown, in m.
Time, in minutes

Fig. V - Coefficient of Transmissibility and storage by Jacob method

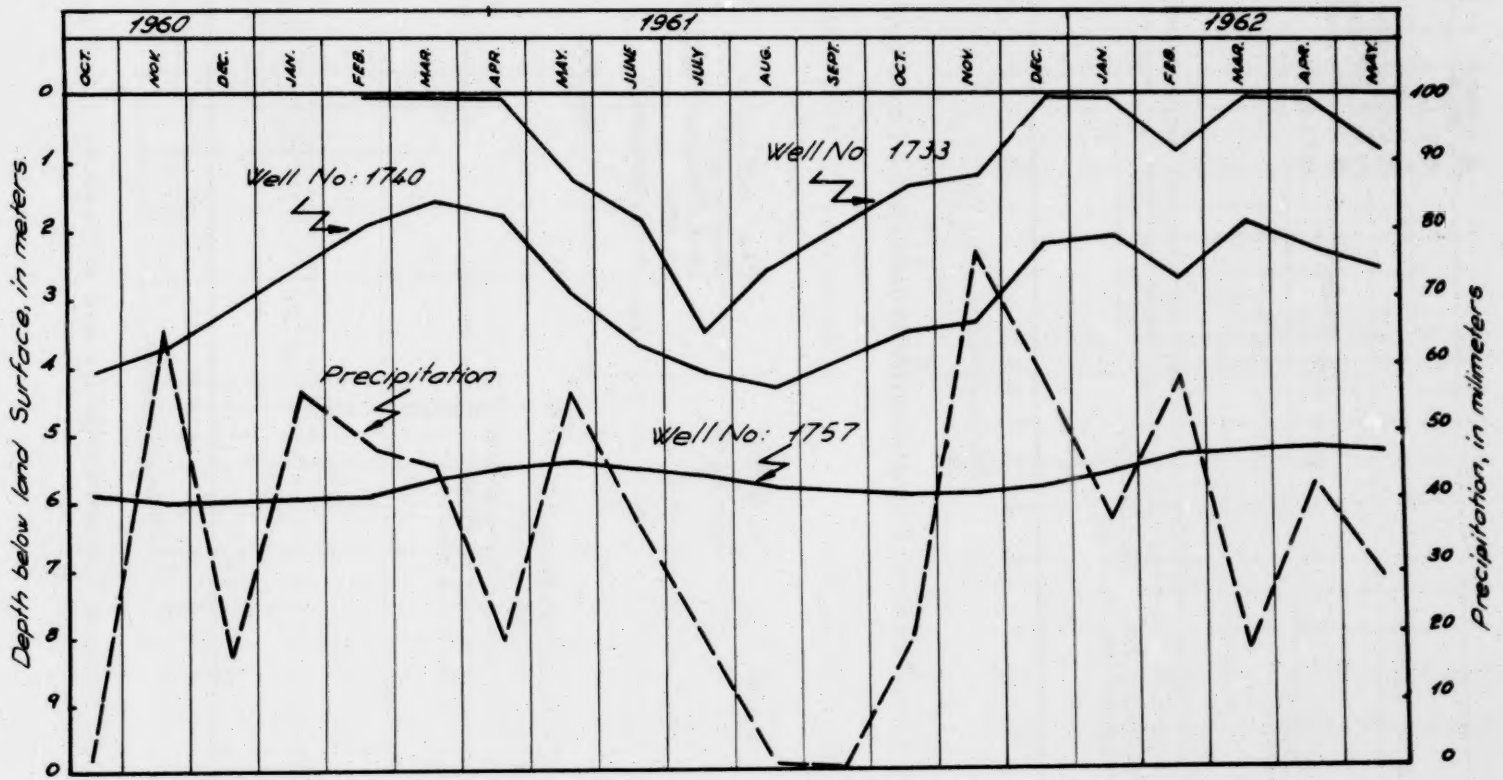


Fig. VI - Hydrographs of wells, and precipitation in Elazig-Uluova Plain

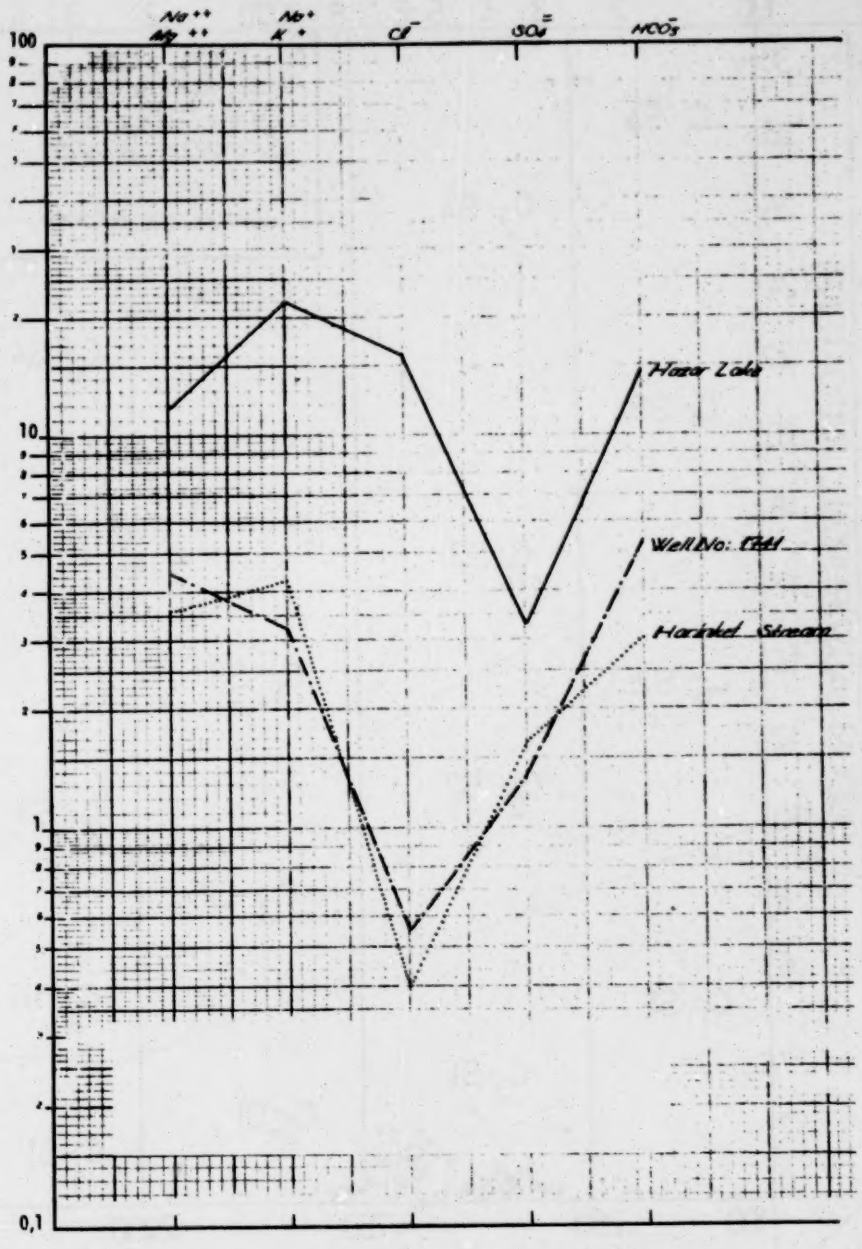


Fig. VII - Semilogarithmic diagram showing the relation between 3 water samples taken from a well from Harinket stream and from Hazor Lake

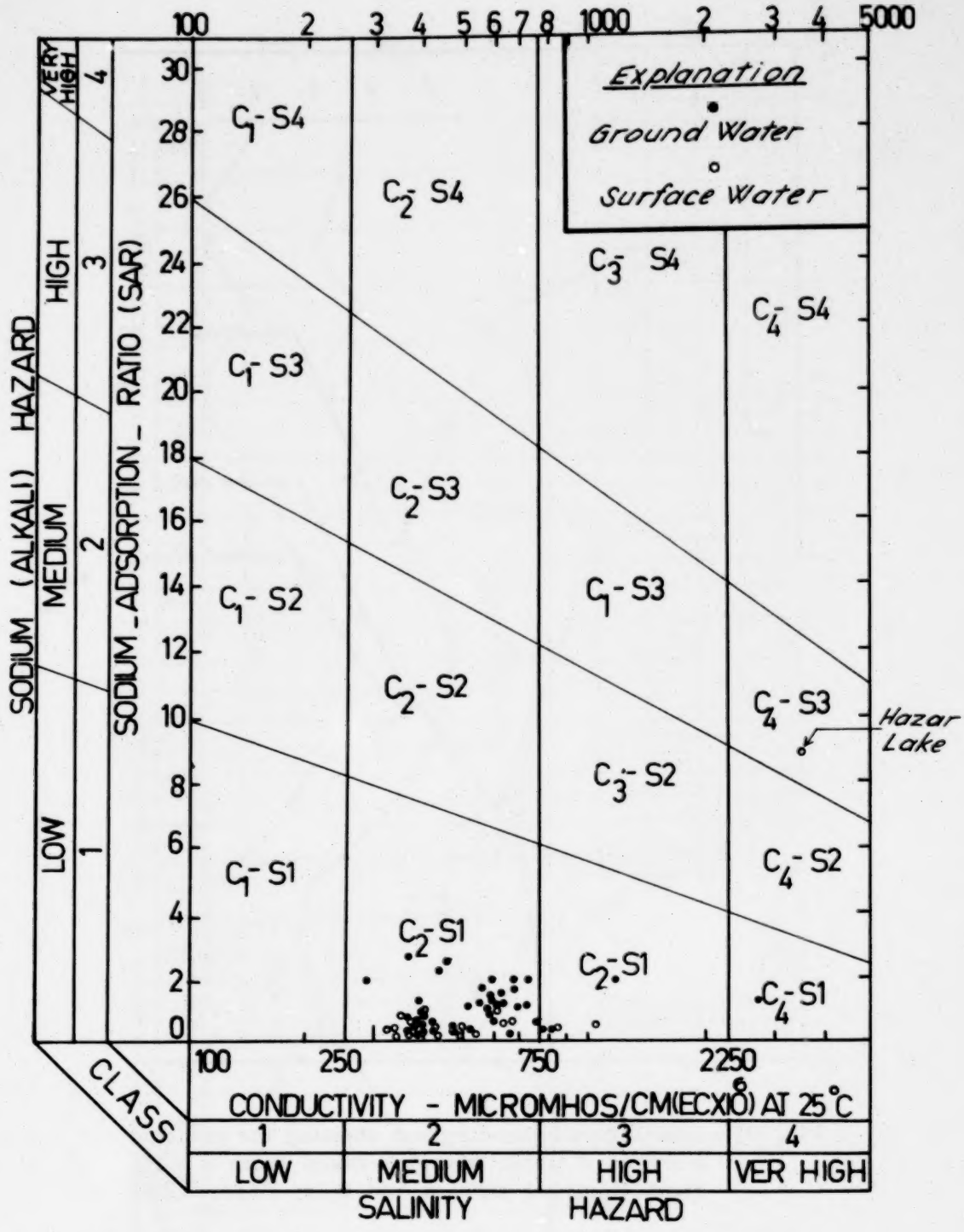


Fig. VIII - Classification of ground-water and Surface water in the Uluova plain

1833 E - Nov. 1962 - 1,600